Lophura hatinhensis is an invalid taxon

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The Vietnamese Pheasant *Lophura hatinhensis* was described in 1975 from one male specimen which was superficially similar to Edwards's Pheasant *L. edwardsi* but for four white (instead of dark metallic blue) tail feathers. Like *L. edwardsi* it is poorly known and highly threatened in the wild. Its status as a species has rarely been questioned despite its curious distribution and dubious morphological distinctiveness. To elucidate the taxonomic status of *L. hatinhensis* we examined the morphology of captive birds of both taxa and analysed mitochondrial DNA. These lines of evidence demonstrated that birds exhibiting the *L. hatinhensis* phenotype probably represent inbred *L. edwardsi*. Thus *L. hatinhensis* should be removed from the IUCN Red List and other checklists of valid extant bird species. Its apparent recent appearance alongside wild populations of *L. edwardsi* might be taken as evidence that wild populations of this species are also highly inbred and possibly close to extinction.

INTRODUCTION

The Vietnamese Pheasant *Lophura hatinhensis* was described by Vo Quy (1975) in his book *Chim Viet Nam* (translation: 'Birds Vietnam') and has been widely recognised as a species ever since (Sibley & Monroe 1990, Inskipp *et al.* 1996, BirdLife International 2001, 2011, Dickinson 2003). However, owing to its close similarity to Edwards's Pheasant *L. edwardsi* it has been considered a subspecies of that species (e.g. del Hoyo *et al.* 1994, Johnsgard 1999), a *species inquirenda* (Vuilleumier *et al.* 1992; also BirdLife International 2001), not recognised at all (Johnsgard 1986) or treated ambiguously (Madge & McGowan 2002, Hennache & Ottaviani 2005). Both *L. hatinhensis* and *L. edwardsi* are extremely rare denizens of low-lying broadleaved evergreen forests in the Annamite Mountains of central Vietnam, and remain very poorly known in the wild (BirdLife International 2001). Both were classified as Endangered until early 2012 when *L. edwardsi* was uplisted to Critically Endangered (BirdLife International 2012a). *Lophura hatinhensis* records derive primarily from the area to the north of the distribution of *L. edwardsi*, although there is one record from Thua Tien Hue province on the southern limit of the range of *L. edwardsi* (BirdLife International 2001).

Male *L. hatinhensis* and *L. edwardsi* are morphologically very similar. The type description of *L. hatinhensis* (Vo Quy 1975) diagnoses the species as (our translation):

> *Lophura hatinhensis* sp. nov. Male (adult): white crest with black at the tip. Black underparts (belly). Head, neck, breast, upperparts and rump (uppertail) are black with glossy purplish-blue. Wing-coverts are dark blue; upperparts and tail-coverts black with black lines at the tip; four central tail feathers pure white, other tail feathers black; wing feathers black. Facial skin and legs red, bill black. Measurements (male holotype): wing 245, tail 270, leg 89, bill 30 mm. Weight 1,100 g. In comparison with closely related pheasants like *L. imperialis*, *L. edwardsi* in Vietnam, *L. inornata* in Sumatra and *L. swinhoei* in Taiwan, the new species is closer to *L. edwardsi*. The only difference is that the new species has a darker colour, no shiny green and four white tail feathers.

Other authors have noted additional differences between the taxa, reporting that *L. hatinhensis* is larger than *L. edwardsi* with a slightly downcurved tail with pointed central tail feathers and longer tarsus, and that both species have pronounced metallic green wings, except in the breeding season when *L. hatinhensis* develops a distinct reddish-purple colour on the wings (Dang Gia Tung & Le Sy Thuc 1996, Hennache *et al.* 1999).

Mitochondrial DNA analyses, using 15 samples of *L. hatinhensis* and six of *L. edwardsi*, suggested that the two taxa are each other's closest relatives (Randi *et al.* 1997, Scott 1997, Hennache *et al.* 2003) and that they diverged within the last 100,000 years (Scott 1997, Hennache *et al.* 1999). Although their phylogenetic relationships could not be accurately determined, Scott (1997) proposed that they should be considered evolutionary significant units. Based on these data Hennache *et al.* (1999) recommended that they should not be allowed to interbreed in captivity.

Despite the widespread acceptance of *L. hatinhensis* as a species, there is considerable uncertainty regarding its diagnosis. Here we present the results of the first thorough investigation into the validity of *L. hatinhensis*, bringing together genetic and morphological data. The histories of the captive populations of the two taxa are of relevance to any discussion of their morphology, and these are therefore documented here. We present previously unpublished genetic data and synthesise morphological data that suggest that individuals that are phenotypically classifiable as *L. hatinhensis* probably represent *L. edwardsi*; we propose that inbreeding is the most likely mechanism for this phenomenon. We believe that *L. hatinhensis* has no taxonomic standing, and therefore that all records of this taxon are attributable to *L. edwardsi*.

MATERIALS AND METHODS

The type description of *L. hatinhensis* apparently involved a single male individual (see above), but the author did not assign it to a particular specimen, nor did he indicate a specimen number, place of deposition of the specimen, or the place and date of its collection. The distribution of the species was given as 'areas of mountainous forest in Ky Anh district, Ha Tinh province' and its status as 'rare in our country' (Vo Quy 1975). Confusion surrounds this description, since according to BirdLife International (2012b) the species was discovered in 1964 and described by 'Vo Quy & Do Ngoc Quang (1965)'. Yet this reference does not appear in the BirdLife reference list and we have only been able to trace one paper by these authors in 1965 whose subject is a collection of birds made in Cao Bang and Lang Son provinces in northern Vietnam (and thus far from Ha Tinh province, which is in central Vietnam) (Vo Quy & Do Ngoc Quang 1965). Rozendaal (1991) also reported that *L. hatinhensis* was described (in Vietnamese in a publication both difficult to obtain and unclearly referenced) from a single male specimen, preserved in the Institute for Ecology and Biological Resources, Hanoi, collected on 26 January 1964 by the late Do Ngoc near Ky Son (Ky Anh district, Nghe Tinh province [name since reverted to Ha Tinh province] c.17°59′N 106°10′E, while a second male was taken in 1974 by Truong Van La at the same locality but was only partially preserved; Robson *et al.* (1989) gave briefer, similar evidence but reported the type locality as 'Song

Table 1. Samples used in the genetic analysis. 'Origin unknown' refers to wild-caught individuals lacking information on collecting location.

Sample ID	Species	Sample	Origin	Captive/wild	Sex	Comments
LED29	*L. edwardsi*	Blood	Jersey Zoo	C	F	Studbook number 502
LED55	*L. edwardsi*	Toepad	MNHN	C (F1)	U	Skin number 878. Born in Clères, France, died 1931
LED56	*L. edwardsi*	Toepad	MNHN – Cam Lo, Quang Tri province	W	M	Skin number 922. Collected 29/12/1923 by J. Delacour
LED57	*L. edwardsi*	Toepad	MNHN – Thua Tien Hue province	W	F	Skin n° 2882. Collected December 1927 by Delacour
LED58	*L. edwardsi*	Feather	Phuong Dien district, Thua Thien Hue province	W	M	Trapped in August 1996
LED59	*L. edwardsi*	Feather	Phuong Dien district, Thua Thien Hue province	W	M	Trapped in August 1996
LED74	*L. edwardsi*	Feather	Hanoi Zoo – Huong Hoa district, Quang Tri province	W	M	Trapped on 23/11/1996
LED107	*L. edwardsi*	Feather	Hai Lang district, Quang Tri province	W	M	Trapped in 2000 and died shortly after
LHA1K	*L. hatinhensis*	Feather	Hanoi Zoo – Minh Hoa district, Quang Binh province	W	M	
LHA2	*L. hatinhensis*	Blood	Hanoi Zoo	W	F	Origin unknown
LHA3K	*L. hatinhensis*	Feather	Clères (France)	C (F1)	M	On breeding loan from Hanoi Zoo
LHA4K	*L. hatinhensis*	Feather	Clères (France)	C (F1)	F	On breeding loan from Hanoi Zoo
LHA5	*L. hatinhensis*	Blood	Hanoi Zoo	W	U	Origin unknown
LHA6	*L. hatinhensis*	Blood	Hanoi Zoo	W	U	Origin unknown
LHA7	*L. hatinhensis*	Feather	Hanoi Zoo	W	F	Origin unknown
LHA8	*L. hatinhensis*	Feather	Private collection, Thailand	W	M	Origin unknown
LHA9	*L. hatinhensis*	Feather	Private collection, Thailand	W	F	Origin unknown
LHA10	*L. hatinhensis*	Feather	Private collection, Thailand	C (F1)	U	
LHA11	*L. hatinhensis*	Feather	Private collection, Thailand	C (F1)	U	
LHA12	*L. hatinhensis*	Feather	Hanoi Zoo	W	U	Origin unknown
LHA13	*L. hatinhensis*	Feather	Hanoi Zoo	W	U	Origin unknown
LHA14	*L. hatinhensis*	Feather	Hanoi Zoo	C (F1)	M	Origin of parents Minh Hoa District, Quang Binh province
LHA15	*L. hatinhensis*	Feather	Hanoi Zoo – Huong Thuy district, Thua Tien Hue province	W	M	Trapped in 1999 when it walked into a farmer's house

Tung'. We were unable to make direct comparisons with the holotype in the preparation of this paper, but one of us (JCE) has previously examined and photographed it (Fig. 13 in Rozendaal 1991).

Morphological analyses

Morphological data were collected from adults, mainly concerning the colour of the neck, mantle and wing-coverts, the number, form and colour of the tail feathers, and the age at which white tail feathers (if any) are developed. These are derived from personal observations by AH (adult *L. hatinhensis*: four wild-caught birds and at least 12 captive-bred birds; adult *L. edwardsi*: one wild-caught male, three museum skins of wild-caught birds and at least 16 captive-bred birds) and by others (in pers. comms. to AH) on the plumage of wild-caught *L. hatinhensis* held at Hanoi Zoo and on captive-bred birds of both taxa held at Hanoi Zoo, in European zoos and in private collections. The history of the captive populations was reconstructed using the international studbooks of *L. edwardsi* (Hennache 2003) and *L. hatinhensis* (Hennache 2008). The *L. edwardsi* studbook was resurrected in 1994 and carefully maintained by AH until 2009.

DNA extraction, amplification and sequencing

Total DNA was extracted from 95% ethanol-preserved tissue (skin or toe-pad) or feather root samples, using procedures described by Randi & Lucchini (1998). The 5' domain of the mitochondrial DNA control region (mtDNA CR) was PCR-amplified and sequenced as previously described (Randi & Lucchini 1998, Randi *et al.* 2001). CR sequences were obtained from living birds that were identified from morphological features as *L. hatinhensis* (n=15; comprising ten wild-caught birds and five F1 generation captive-bred birds derived from wild birds), birds which showed morphological features of *L. edwardsi* (n=8; comprising two birds collected during the 1920s and 1930s, four wild birds collected since 1996, one modern captive-bred individual and one captive individual born in the 1930s from wild-caught parents) (Table 1) and *L. swinhoei* (Swinhoe's Pheasant, n=1), a closely related outgroup. The CR sequences were aligned using CLUSTAL X with the default options (Thompson *et al.* 1997). Phylogenetic analyses were performed using the software PAUP* (Swofford 1998) by: (1) a maximum-parsimony procedure (Swofford 1998), excluding all uninformative nucleotide positions, with unordered and equally weighted characters; (2) the neighbour-joining algorithm (Saitou & Nei 1987), with Tamura & Nei's (1993) DNA distances. Robustness of the phylogenies was assessed by bootstrap percentages (BP: Felsenstein 1985), with 1,000 random resamplings with replacement. Details on phylogenetic analyses are given in Randi *et al.* (2001).

RESULTS

Morphological analyses

The *L. edwardsi* studbook revealed that the captive stock is derived from 28 specimens, of which only 6–8 were females, collected between 1924 and 1930, and never subsequently supplemented with wild birds (Ciarpaglini & Hennache 1997). It is therefore highly inbred, particularly in America where birds are derived from an even smaller subset of founders imported from France and England before World War II. The *L. hatinhensis* studbook is more

recent: the first record of the taxon in captivity was in 1990 when Hanoi Zoo obtained six wild-caught *L. hatinhensis* (four males and two females) from hunters. These were reportedly caught in Minh Hoa district (Quang Binh province), but further information about the location of their capture is unfortunately unavailable. Two males and one female died shortly afterwards from injuries sustained during their capture. In 1991 Hanoi Zoo purchased an additional female so that it had two pairs of *L. hatinhensis* for captive breeding. During the following seven years nearly 50 chicks were hatched in Hanoi Zoo from these two pairs and their offspring, and a few additional wild birds were purchased to augment the population. In 1996 the first *L. hatinhensis* (two male and two female F1 generation captive-bred birds) to be exported from Vietnam were received at Clères, France, where they bred the following year. The descendants of this pair were distributed widely in Europe, thus establishing the European captive stock. There are reportedly no *L. hatinhensis* in the USA and no importation there is documented.

Observations of captive-bred and wild-caught birds have indicated that the plumage of *L. hatinhensis* is unstable and exhibits more variation than the type description and other sources would suggest (Corder 1996, Dang Gia Tung & Le Sy Thuc 1996, Davison 1996). There is variation in the number, distribution and morphology of white tail feathers and in the timing of their development. Observations of captive male *L. hatinhensis* have shown that the 'diagnostic' white tail feathers normally develop after the first adult moult, when the bird is 18 months old, although in some individuals they appear earlier (at 15 months) or do not appear until the bird is 24 or even 30 months old (Dang Gia Tung & Le Sy Thuc 1996, AH pers. obs.).

The number of white tail feathers exhibited by *L. hatinhensis* is variable and ranges from one to six; moreover, they are often distributed asymmetrically (Dang Gia Tung & Le Sy Thuc 1996, AH pers. obs.). Their morphology varies individually (AH pers. obs.). The feathers may be entirely white or partially white with brownish streaks and patches. For instance, a male *L. hatinhensis* which died on 10 November 1999 aged 30 months at Cau Dien Breeding Centre (Vietnam) had one white tail feather to the left of the centre of the tail and two feathers (one to the left and one to the right of the centre of the tail) which exhibited a mix of brown and white patches, one of which was entirely brown except the white tip (Plate 1). Moreover, the occurrence of white in the plumage of *L. hatinhensis* is not always limited to the central tail feathers: a male *L. hatinhensis* (identified by its white tail feathers) caught near Hue in 1999 and subsequently retained in Hanoi Zoo developed white tertials after its first moult in captivity (Plate 2).

The female *L. hatinhensis* is very similar to that of *L. edwardsi*, as Rozendaal (1991) showed: body plumage and wing-coverts chestnut, head and neck tinged grey; remiges dark brown, vermiculated with chestnut on the inner vane, outer web pale brown; tail incomplete, three outer pairs of rectrices blue-black, the outermost rectrix with brown basal half of outer web; presumably at least two central pairs of rectrices with more brown. Bill dark horn, orbital skin and feet scarlet, iris dark brown. Thus it appears not to differ substantially from female *L. edwardsi*, except perhaps for the warmer tone to the underparts. Although some authors have claimed that it has more reddish-chestnut plumage (Dang Gia Tung & Le Sy Thuc 1996, Hennache *et al.* 1999) there is considerable individual variation in captive individuals. Some captive female *L. hatinhensis* are indistinguishable on plumage from female *L. edwardsi*, whilst others possess 1–4 central tail feathers which may be entirely white or, more often, brown with white borders and streaks.

Morphological features thought to be unique to *L. hatinhensis* have arisen in pure-bred captive lines of *L. edwardsi* and in some individuals typical *L. edwardsi* plumage features have been lost

Plate 1. Tail feathers of a male *L. hatinhensis* which died in Cau Dien Breeding Center in 1999 showing variable pattern of white on tail feathers. (Alain Hennache)

Plate 2. Dorsal view of a male *L. hatinhensis* caught near Hue in 1999 and subsequently retained in Hanoi Zoo that developed white tertials after its first moult in captivity. (Alain Hennache)

(Corder 1996). Towards the end of 1999 at Clères, France, a six-year-old male *L. edwardsi* with a history well documented in the international studbook (its parents were traced back to four different bloodlines) developed three white tail feathers on the centre-left and two on the centre-right of its tail: morphologically it had become indistinguishable from *L. hatinhensis* (Plate 3). In 1998 a female *L. edwardsi* held at a collection in Germany developed one white central tail feather when it was three years old (Plate 4). In 1997 a male *L. edwardsi* held at a collection in Alabama, USA, developed

Plate 3. Tail of male *L. edwardsi* born in France 1993 (international studbook number 586) showing two partially white tail feathers that developed after six years. (Alain Hennache)

Plate 4. Tail of female *L. edwardsi* born in Germany 1995 (international studbook number 882) showing one white tail feather. (Alain Hennache)

white tail feathers (Plate 5). Inbreeding has led to a number of other morphological changes in the captive population of *L. edwardsi*: in the 1970s the crest was reduced or absent on some birds (Lovel 1979) and in 1999 birds imported from the USA were on average a third smaller than European captive birds (AH pers. obs.).

The other morphological features mentioned by Vo Quy (1975) as unique to *L. hatinhensis*, namely a lack of shiny green feathers and darker plumage, have on examination of a larger number of captive-bred and wild-caught birds been shown to be invalid (Dang Gia Tung & Le Sy Thuc 1996, Hennache *et al.* 1999).

Genetics

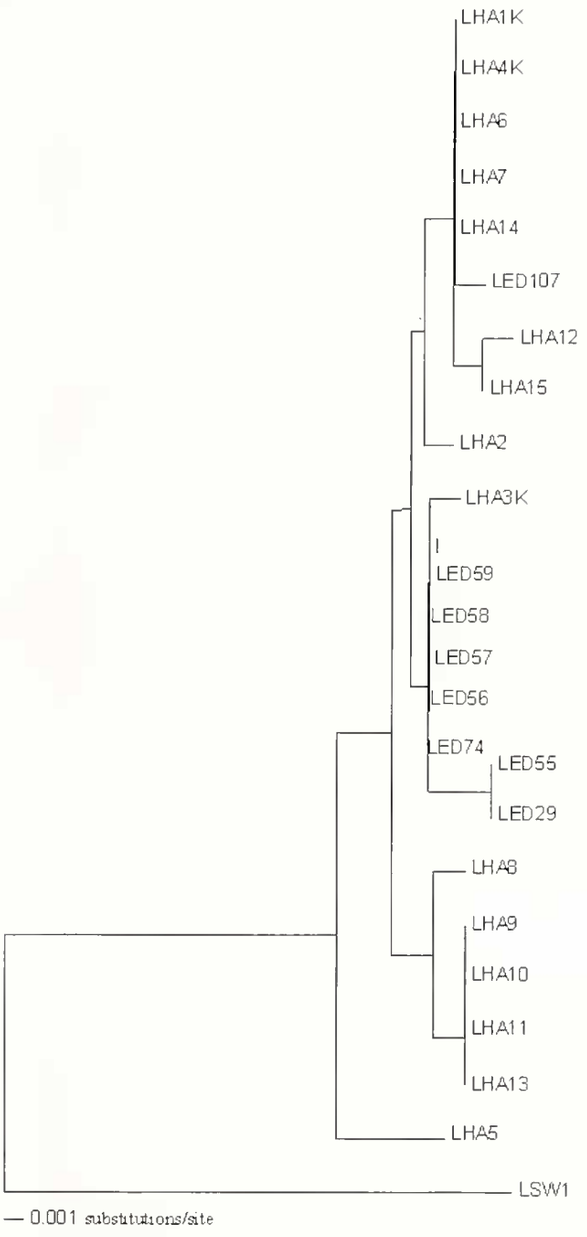
The relationships of the *L. hatinhensis* and *L. edwardsi* mtDNA CR sequences are described by the neighbour-joining tree (Figure 1). Sequences of *L. hatinhensis* are very similar to those of *L. edwardsi* with a low level of sequence divergence (mean 0.6%, max 1%). *Lophura hatinhensis* shows eight mtDNA haplotypes of which one clusters within *edwardsi* (LHA3). *Lophura edwardsi* shows three haplotypes of which one (LED 107) clusters within one group of *L. hatinhensis*. With the exception of LED 107, all the recent and historical wild *L. edwardsi* have the same haplotype, which differs slightly from the captive stock (LED 29 and LED 55). The neighbour-joining tree represented in Figure 1 is based on c.700 nucleotides. Bootstrap values were typically very low.

Plate 5. Male *L. edwardsi* born in Alabama, USA, which developed white central tail feathers in 1997. This bird phenotypically resembles *L. hatinhensis*. (Michel Klat)

DISCUSSION

Lophura hatinhensis is a species with a very short history. It was discovered in 1964 and described in 1975; fewer than 50 individuals have been recorded in the wild with any degree of certainty and of those 22 were already dead and at least seven were taken into captivity (BirdLife International 2001, AH pers. data). Our data demonstrate that *L. hatinhensis* is characterised by little genetic differentiation from *L. edwardsi*. Morphological analysis has shown that individual *L. edwardsi* of known pedigree can develop plumage features that ostensibly render them indistinguishable phenotypically from *L. hatinhensis*. We have also documented variation within the *L. hatinhensis* tail phenotype and shown that it is unstable and does not conform neatly to the 'middle four white tail feathers' described by Vo Quy (1975). Other plumage features

Figure 1. Neighbour-joining tree showing phylogenetic relationships of the sequenced mitochondrial DNA control regions of *L. edwardsi*, *L. hatinhensis* and *L. swinhoei* (LED, *L. edwardsi*; LHA, *L. hatinhensis*; LSW, *L. swinhoei*).



previously described as unique to *L. hatinhensis* have already been shown to be irrelevant (Dang Gia Tung & Le Sy Thuc 1996, Hennache *et al.* 1999). Taken together these findings demonstrate that *L. hatinhensis* has no taxonomic standing. We therefore suggest it be removed from the IUCN list of threatened species, and all other relevant extant bird checklists. This reduces the number of Vietnamese endemic *Lophura* to one: *L. edwardsi*. The other enigmatic Vietnamese endemic *Lophura*, *L. imperialis*, has already been shown to represent a hybrid between *L. edwardsi* and Silver Pheasant *L. nycthemera*, based on genetic and morphological evidence and captive-breeding experiments (Hennache *et al.* 2003).

Although our morphological study relies almost entirely on captive birds, *L. edwardsi* is so poorly known in the wild that data are insufficient for a thorough analysis. In addition, captive birds are of known heritage and can therefore reveal details about morphology that observations of wild individuals of unknown parentage could not. If an individual *L. edwardsi* were to develop white tail feathers in a wild state it would just be assumed to represent *L. hatinhensis*; indeed this is probably what happened to the male caught near Hue (within the range of *L. edwardsi* and far to the south of previous records of *L. hatinhensis*) in 1999.

Albinism in birds is thought to result from the expression of recessive alleles that disrupt melanin pigmentation at feather development (Bensch *et al.* 2000). These alleles are usually only expressed when the population is highly inbred. This phenomenon is well known to breeders who have reared birds over many generations without change to the bloodlines. Even when populations are highly inbred, characters which arise owing to inbreeding do not usually become fixed; for instance, in an isolated population of Great Reed Warblers *Acrocephalus arundinaceus* with a small founder stock partial albinism was only recorded during the first five years of the colony's existence (Bensch *et al.* 2000). In contrast, the presence of white tail feathers in *L. hatinhensis* has become at least partially fixed, and this is perhaps because of the prevalence of a white (or buff) tail feathers in the genus *Lophura*. *Lophura edwardsi* and Siamese Fireback *L. diardi* are unique among *Lophura* pheasants in that they do not possess any white or buff tail feathers, the presence of which otherwise characterises the genus. Mutations expressed in captive *Lophura* of other species as a result of inbreeding have resulted in birds with additional white tail feathers. For instance, in Australia where the captive population of *L. swinhoei* is highly inbred, several males developed a second pair of white central tail feathers and one male developed five white tail feathers and a larger white crest (Weber 1992). The *L. edwardsi* captive stock is highly inbred; indeed all captive-bred birds analysed by Randi *et al.* (1997) have the same nucleotide sequence at the mtDNA control region compared with five wild-caught *L. edwardsi* which exhibited nucleotide substitutions, a result which is perhaps unsurprising since the captive-reared birds were all derived from a single female. The prevalence of white tail feathers in *Lophura* perhaps explains why it is this feature that is the primary visual manifestation of inbreeding in *L. edwardsi*. An alternative explanation for the expression of white tail feathers in captive *L. edwardsi* would be that these birds represent hybridisation with *L. hatinhensis*. However, the timing of the birth of the three European captive *L. edwardsi* that developed white tail feathers precludes any chance that they are the result of such hybridisation, since they were hatched before *L. hatinhensis* was first exported from Vietnam.

Unfortunately it was not possible to compare genetic and morphological data presented in this study with the type specimen of *L. hatinhensis*. However, it is unlikely that any of our conclusions would have changed as a result of this. Although some of Vo Quy's (1975) measurements of the type specimen are larger than all *L. edwardsi* measured by Oustalet (1896) and Delacour (1977) (Table 2), this bird is only marginally larger and some of the more striking differences, especially tarsus length, may be the product of differences in methods for taking measurements. With a larger sample size (Vo Quy only measured one *L. hatinhensis*) the measurements might be found to overlap with those for *L. edwardsi*. All *L. hatinhensis* examined by AH show no differences in size, colour or intensity of gloss from captive *L. edwardsi*. Therefore the only morphological feature that can be used to identify *L. hatinhensis* is the presence of one or more white or partially white tail feathers, and our data indicate that these can arise in lines of inbred pure-bred *L. edwardsi*.

Lophura hatinhensis and *L. edwardsi* exhibit shallow genetic differentiation at a level that does not support their species-level separation. Research has shown that pheasant species pairs typically show genetic divergence of at least 2% (Randi *et al.* 2001). For instance, *L. edwardsi* and *L. swinhoei* differ by 2.5%, *L. leucomelanos* (Kalij Pheasant) and *L. nycthemera* by 2.8% (or 2.5%: Moulin *et al.* 2003), *L. diardi* and *L. ignita* (Crested Fireback) by 4.4% (Randi *et al.* 2001) and *Tragopan* species pairs by 3.6–5.9% (Randi *et al.* 2000). Our application of the mtDNA genes uncovers considerable differentiation among closely related pheasants (see Figure 2 in Hennache *et al.* 2003). Sampling was insufficient to determine

Table 2. Published measurements in mm of male *L. edwardsi* and *L. hatinhensis*. Numbers constitute means unless more than one number is given.

Taxon	No. Birds	Length(head-body)	Wing	Tail	Culmen	Tarsus	Source
L. edwardsi	3	580	230	220	30	83	Oustalet 1896
L. edwardsi	14	580–650	220–240	240–260	30	75	Delacour 1977
L. hatinhensis	1	–	245	270	30	89 ('feet')	Vo Quy 1975

whether the nine mtDNA haplotypes apparent in the neighbour-joining tree represent geographic differentiation, although this seems very unlikely. Data in Hennache *et al.* (2003) indicated that, when compared with each other, *L. hatinhensis* showed five unique alleles and *L. edwardsi* eight. However, all *L. edwardsi* examined were captive birds from a highly inbred line, and these data are therefore thought to indicate a loss of alleles from the captive population of *L. edwardsi* rather than evidence of unique alleles in the population of *L. hatinhensis*.

With the exception of the one bird found in Thua Tien Hue province (mentioned above), located to the south of the range of *L. edwardsi*, all records of *L. hatinhensis* derive from the area to the north of the range of *L. edwardsi*. Were it not for the Thua Tien Hue bird it would be plausible that *L. hatinhensis* represents a northerly subspecies of *L. edwardsi*. However, to support the subspecies theory the bird from Thua Tien Hue province must be considered an aberrant *L. edwardsi* whose appearance coincidentally matches that of true *L. hatinhensis*. Moreover, the appearance of captive *L. edwardsi* superficially resembling *L. hatinhensis* in inbred lines would then have to be explained as a coincidence and the unstable phenotype of *L. hatinhensis* ignored. The improbability of these circumstances is so high that the burden of proof must now be on those who would seek to uphold the validity of this taxon, whether as a species or a subspecies.

Based on the occurrence of white tail feathers in inbred captive populations of *L. edwardsi* we propose that inbreeding might be the mechanism that has caused the occurrence of the *L. hatinhensis* phenotype in the wild; this was first proposed by Hennache & Ottaviani (2005). Following this theory, we suggest that records of wild birds with the *L. hatinhensis* phenotype have been made on the northern and southern periphery of the range of *L. edwardsi*, suggesting that at least outside of the core range (where there have been no records since the late 1990s) the wild population is fragmented and possibly very inbred. It has taken approximately 35 generations for the captive population of *L. edwardsi* to develop the *L. hatinhensis* phenotype, despite originating from a tiny founder population. This indicates that the processes that have led to the dominance of the *L. hatinhensis* phenotype in some wild populations of *L. edwardsi* have been acting since its discovery, and probably long before. *Lophura edwardsi* is now very rare in the wild: there have only been two unequivocal records since 2000, a male trapped in Hai Lang district, Quang Tri province (which later died) and a male found in a farmer's cage in Quang Tri province in 2009 (Dan Tri 2009). It is even conceivable that there are now no remaining wild populations of *L. edwardsi* (*Babbler* 39 [November 2011]: 41). Any remaining populations may either exhibit the *L. hatinhensis* phenotype or have not yet developed it, but like the captive populations they may already be so inbred that the appearance of such a phenotype is only a matter of time. Whilst the captive population is known to derive from a very small founder stock the genetic diversity of the wild population is unknown. In addition to showing white tail feathers, inbred birds might possibly exhibit physiological characteristics, such as reduced fertility or higher mortality rates, which might mean that populations showing the *L. hatinhensis* phenotype are unlikely to persist in perpetuity. As an example, at the end of the 1960s, *L. edwardsi* was increasingly difficult to breed reliably in the United Kingdom and many eggs laid were infertile (Lovel 1979).

The low genetic diversity of the captive population of *L. edwardsi*, and the recent appearance in it of birds which could be classified as *L. hatinhensis*, serve as a warning that this population is not an adequate safety net for restocking areas where wild populations have become extinct. Even captive populations that have not yet developed the *L. hatinhensis* phenotype might yet do so, and care should be taken in managing the captive population to maximise genetic diversity. Although our research has brought some clarity to an enigmatic taxonomic situation, it also indicates that *L. edwardsi* may be closer to extinction and more difficult to rescue than previously thought. If wild populations of the inbred *L. hatinhensis* phenotype can be found it might be prudent, after breeding experiments, to introduce a small number of genetically pure captive-bred birds which still show the *L. edwardsi* phenotype, in the hope that since they were derived from birds collected many years ago they may introduce some lost genetic diversity into the wild population and rescue them from possible inbreeding depression.

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